

FORWARD MODELING OF STRATIGRAPHIC SEQUENCES AT CONTINENTAL MARGINS

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LONG-TERM GOALS

The goal of the Stratigraphy project of the STRATAFORM program is *to understand the creation of the preserved stratigraphic record on continental shelves and slopes as the product of physical processes acting with spatial and temporal heterogeneities*. I am using numerical models to provide insight into the formation and preservation of stratigraphic sequences at margins. My goal is to obtain a quantitative understanding of the interactions of environmental parameters and their influence on stratal architecture and facies distribution. I wish to be able decipher the stratigraphy on margins to read the geologic record of the past and predict future stratigraphy.

OBJECTIVES

I wish to understand how sea level and other factors control the formation of the stratigraphic record at margins. The stratigraphy at margins is packaged into unconformity-bound sequences whose form and lithology record the active processes at the margin. The influences of individual processes that create these sequences are only partly understood. My aim is to quantitatively determine the system response of margins to different forcing functions sufficiently to be able to both predict stratigraphy and invert observed sequence architecture for geologic history.

APPROACH

I am using numerical models as a tool to provide insight into the formation and preservation of stratigraphic sequences at continental margins. In conjunction with others, I have constructed an interactive computer model of stratigraphic sequences at continental margins, and am applying these models to the STRATAFORM field areas. The work is proceeding along three lines:

- (1) Development of 2-D models focused on combining parameterizations of the dynamic sedimentologic and morphologic processes that control sediment deposition and erosion within a framework that accounts for geologic processes that effect accommodation .
- (2) Numerical experimentation with the model to determine the stratigraphic consequences of the processes and parameter interactions. Examination of margin data to calibrate the model.
- (3) Analysis of the geologic record sedimentary and geomorphologic processes in NJ and CA. A particular focus is backstripping to reconstruct the margin development. The modeling of the two margins provides constraints for unraveling the control of sequence development.

WORK COMPLETED

The interactive X-Window graphical user interface for the stratigraphic modeling software has been further updated. These allow more complex manipulation of input and output. The algorithms for calculating the stratigraphy have been improved for faster, more accurate and more stable computations. Considerable debugging of the code has been accomplished. We have performed sensitivity experiments to investigate the model response. We have begun forward model runs aimed at simulating the New Jersey and Eel River margins (Fig. 2). Comparisons of the simulations to observed seismic and well data has begun.

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The digitized sequence stratigraphic interpretation for New Jersey margin has been farther seaward extended across the outer continental shelf and onto the upper continental slope using line 1002 from the Ewing 9009 cruise and line 051 of the STRATAFORM Oceanus 270 cruise. These seismic lines cross the shelf near the by ODP Leg 174A sites and were used to predict paleowater depths at the drill sites. I have used this profile crossing the entire margin for 2-D backstripping to reconstruct the Oligocene-Recent development of the NJ margin (Fig. 1).

RESULTS

Experiments indicate that the shoreface and clinoform rollover do not respond similarly to sea level. Clinoform progradation commonly begins during the transgression. This behavior has not been previously recognized. Variation in some parameters also yielded unexpected interactions.

Backstripping of the NJ margin has improved geologic history of the margin. In the Eocene, the NJ margin was a carbonate ramp dipping at $>1:300$. The shelf edge lay at >500 m water depth. Enhanced terrigenous sediment supply starting in the Oligocene caused progradation of clinoforms across the margin creating a new shallower shelf (Fig. 1). The new reconstructions image the progradation of the new shelf edge past the relict shelf edge. This appears to coincide with the initiation of greater mass flow deposits on the slope and rise.

Numerical experiments for NJ have been undertaken with an initial slope corresponding to the Eocene ramp margin. This resulted in clinoforms that steepened as they prograded into deeper water, consistent with observations and the backstripping. The simulations predicted extensive progradation during transgressions and the formation of oblique, truncated clinoforms during sea level fall. These results are very similar to findings of recent ODP Leg 174A drilling. The modeling and drilling results conflict with existing models of sequence development at margins.

Initial models of the Eel River shelf predict a complex pattern of erosion surfaces separating packages of regressive shorefaces interfingering with transgressive or minor lowstand to wedges near the shelf edge. These strata are covered by a relatively thick Holocene transgressive sheet. Earlier transgressive sheets were almost entirely eroded during subsequent sea level falls. The changing shape of the shelf profile during sea level fluctuations greatly influences preservation.

IMPACT/APPLICATIONS

Sequence stratigraphic models will have to be revised to deal with differences between sequence architecture as imaged by clinoform geometry and facies patterns as mapped by shoreface stacking patterns. Implications of the presence of sharp-based shorefaces need revision.

The changes in margin morphology and sediment supply seen at NJ appear to be widespread and apply to numerous other margins. They are hypothesized as being related to the climatic changes of the Cenozoic.

TRANSITIONS

Software is being used at Old Dominion University and the University of Edinburgh for both STRATAFORM and other sequence stratigraphic investigations. Will shortly be distributing software more widely. Reconstructions were used for predicting strata for ODP Leg 174A.

RELATED PROJECTS

I have developed a parameterized model for estimating flexural rigidity. This model is being used for rigidity estimates in my backstripping calculations and forward modeling.

Reconstructions of West African margins indicate strong similarities with the NJ margin. I am investigating whether the changes in morphology and sediment supply are related to global climate.

REFERENCES

Steckler, M.S., Syvitski, J., D.J.P. Swift, J. Goff and A.W. Niedoroda,. Modeling the sedimentology and stratigraphy of continental margins, *Oceanography*, 9, 183-188, 1996.

- Syvitski, J., L. Pratson, M. Perlmutter, P.L. de Boer, G. Parker, M. Garcia, P. Wiberg, M. Steckler, D. Swift, H. Lee, Earthworks: A large scale and complex numerical model to understand the flux and deposition of sediment over various timescales, V. Pawlowsky-Glahn (ed.), Proceed. of IAMG'97, The Third Annual Conference of the International Association of Mathematical Geology, International Center for Numerical Methods, Barcelona, Spain, 29-33, 1997
- Steckler, M.S., G.S. Mountain, K.G. Miller and N. Christie-Blick, Reconstruction of Tertiary clinoform progradation on the New Jersey passive margin by 2-D backstripping, Marine Geology, in press.
- Swift, D.J.P., J. Carey, Y. Zhang, C.R. Reed, A.W. Niedoroda and M.S. Steckler, Quaternary stratigraphy and sedimentation on the northern California continental margin constrained by numerical modeling: Preliminary results, Marine Geology, submitted.
- Steckler, M.S., C.W. Reed, D.J.P. Swift, and A.W. Niedoroda. High resolution sequence stratigraphic modeling: 1. The interplay of sedimentation, erosion and subsidence, in J. Harbaugh, L. Watney, G. Rankey, R. Slingerland, R. Goldstein and E. Franseen (eds.) Numerical Experiments in Stratigraphy, SEPM Memoir, submitted.
- Carey, J.S., D.J.P. Swift, M.S. Steckler, C. Reed and A. Niedoroda, High resolution sequence stratigraphic modeling: 2. The influence of sedimentation processes, in J. Harbaugh, L. Watney, G. Rankey, R. Slingerland, R. Goldstein and E. Franseen (eds.) Numerical Experiments in Stratigraphy, SEPM Memoir, submitted.
- Reed, C.W., A.W. Niedoroda, D.J.P. Swift, Y. Zhang, J. Carey, and M.S. Steckler, Coastal evolution: Modeling fabric and form at successive spatial scales, Proceed. Intern. Conference on Coastal Research through Large Scale Experiments, submitted.

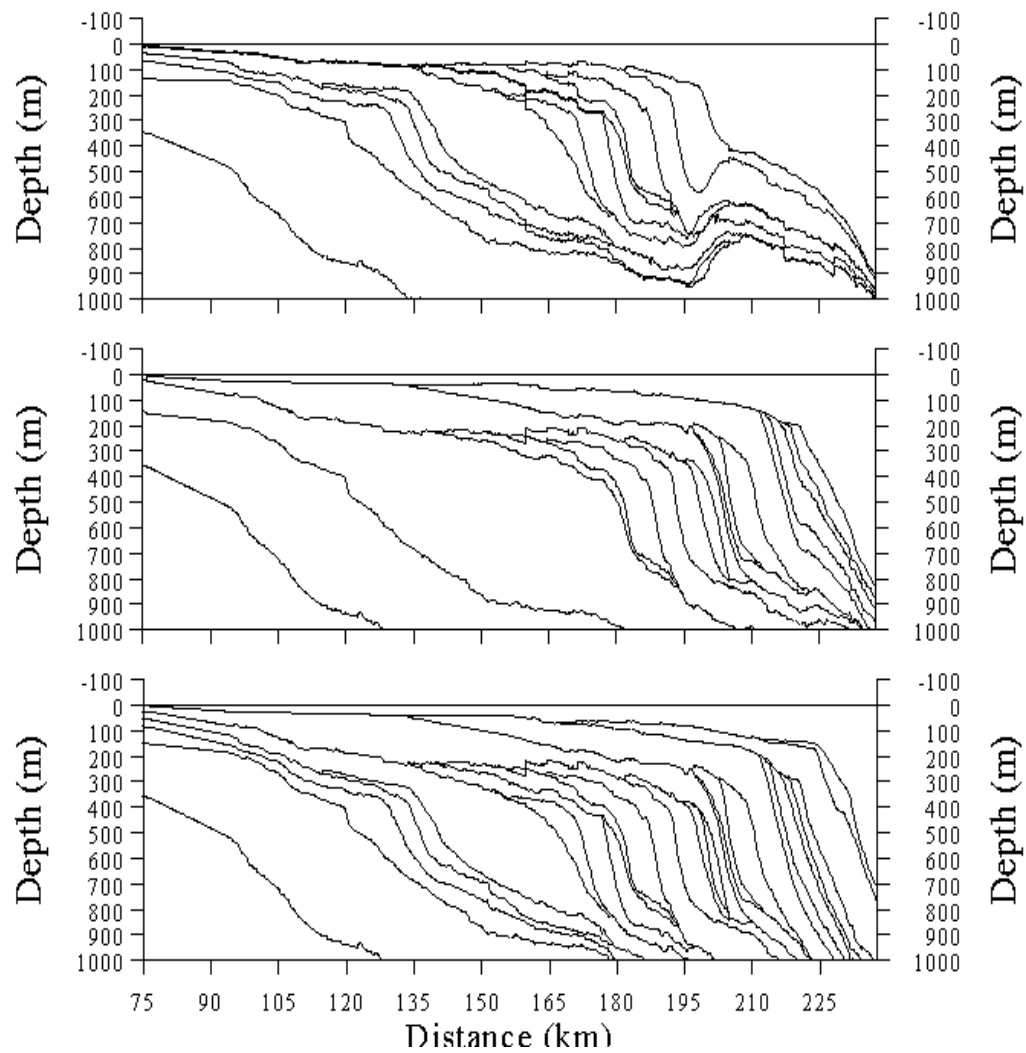


Figure 1. Three timesteps from reconstructions of the New Jersey margin showing the progradation of clinoforms across the preexisting ramp margin. The top shows the margin at sequence m1 (~11.4 Ma). The series of Miocene sequences has filled most of the space above the ramp margin, whose shelf break is visible at km 225. The middle shows sequence pp3 (1.7 Ma). The strata has prograded over the Eocene shelf break. Note the series of oblique clinoforms that form part of this sequence. The bottom shows the present-day configuration of the margin.

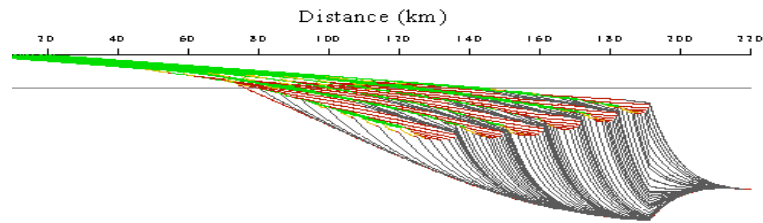


Figure 2. Simulation of progradation of several sequences across a steep ramp margin. The model is driven by falling sea level with an 80-m amplitude 400 ky cyclicality. Time lines are drawn every 20,000 years colored as follows: green - non-marine, yellow - shoreface, maroon - marine shelf, gray - clinoform foresets. Note the increase in clinoform height and slope that develops. The topsets consist primarily of onlapping shelf strata deposited during transgressions capped by nearshore to nonmarine strata. Progradation is characterized by oblique clinoforms. These features compare well with the recent (July-Aug., 1997) drilling results.